Evidentiary Basis of Percutaneous Discectomy

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8.1 Background

The intervertebral disc is part of an anatomic unit that consists of an inner gelatinous nucleus pulposus (NP), an outer annulus fibrosus (AF), and the cartilaginous endplates with their associated capillary beds both cranially and caudally. The central NP is a site of collagen secretion and contains numerous proteoglycans (PG), which facilitate water retention, creating hydrostatic pressure to resist axial compression of the spine. The NP is primarily composed of type II collagen. In contrast, the AF functions to maintain the NP within the center of the disc with low amount of PG and is composed of primarily of type I collagen [1, 2].

The intervertebral disc is one of the largest avascular tissues in the body. Disc tissues derive their nutrition from vessels in the subchondral bone adjacent to the hyaline cartilage of the endplate. Small molecules, such as glucose and oxygen, are carried through the endplate in a passive diffusion process.

The disc matrix is produced by chondrocytes in the nucleus pulposus (NP), and synthesis is promoted by factors such as transforming growth factor (TGF) and insulin-like growth factor (IGF). Under normal conditions, the matrix is in a continuous state of renewal and degradation. The chondrocyte produces enzymes, known matrix metalloproteinases (MMPs), which degrade the matrix. These enzymes are controlled by tissue inhibitors of matrix metalloproteinases (TIMMPs) [3].

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Several changes in the biology of the intervertebral disc may lead to the herniation of the NP through the AF and compression of the thecal sac. These include reduced water retention in the NP, increased percent of type I collagen within the NP and inner AF, degradation of collagen and extracellular matrix (ECM) materials, and upregulation of systems of degradation such as apoptosis, matrix metalloproteinase (MMP) expression, and inflammatory pathways [1, 4, 5]. Axial overloading is another theory for disc herniation that could occur independent of degenerative disease. A subset of patients with LDH lack evidence of severe degenerative disc, thus herniation occurs as a result of spinal overloading [6].

In lumbar disc herniation (LDH), narrowing of the space available for the thecal sac can be due to a protrusion of the disc through an intact AF (contained), an extrusion of the NP through the AF but still maintaining continuity with the disc space (non-contained), or a complete loss of continuity with the disc space and becoming a free fragment (sequestered) [4]. The herniated disc could directly compress the nerves or illicit an inflammatory response in the adjacent neural elements.

The primary signs and symptoms of LDH are radicular pain, sensory abnormalities, and weakness in the distribution of one or more lumbosacral nerve roots. Although the first descriptions of sciatica go back to ancient times, our understanding of LDH as a clinical entity arose in the mid-1700s. Early surgeries for spinal "enchondromas," which very likely were herniated discs, were performed in the first part of the twentieth century [7].

Modern discectomy surgery is usually traced to Mixter and Barr [8] in 1934 when they reported on the open surgical treatment for ruptured intervertebral discs through a laminectomy approach, thereby heralding the beginning of "disc surgery." With the development and advancement in diagnostic and surgical techniques, the surgical approaches became less invasive so that hemilaminectomies were the standard surgical approach for the majority of disc herniations at the beginning of the 1970s [9].

In 1977, Yasargil removed a herniated disc using an operative microscope [10], a technique known as "microsurgical discectomy" or "microdiscectomy," which describes the removal of herniated parts of lumbar intervertebral discs through a posterior approach with the help of a surgical microscope and microsurgical instruments [11].

Despite the significant improvements in surgical treatments of LDH, there were still substantial complications and significant rates of developing "failed back surgery syndrome" (FBSS), otherwise known as "post laminectomy syndrome" [12]. The search for minimally invasive techniques led to the development of percutaneous disc decompression or percutaneous discectomy (PD).

8.2 Discussion

The concept behind percutaneous discectomy states that in a contained disc herniation, in which the nucleus pulposus and annulus fibrosis are within a closed hydraulic system, a small reduction in central nucleus pulposus volume causes a large

reduction in intradiscal pressure. This allows the nuclear jelly-like material of the herniation to ooze back into the newly created space "Jelly donut theory," decompressing the nerve root responsible for the radicular pain or decreasing inflammatory mediators causing irritation of the nerve root. Thus *a contained disc* is an important prerequisite to the success of PD [9, 13].

The first version of percutaneous discectomy could be attributed to Smith [14], who coined the term chemonucleolysis to describe the enzymatic dissolution of the nucleus pulposus as an alternative and less invasive means of decompressing the herniated disc than surgical discectomy.

In 1975, Hijikata [15] described manual percutaneous lumbar discectomy. And in 1985, Onik et al. [16] described automated percutaneous lumbar discectomy, a minimally invasive method with the aspiration of disc material using a suction cutting device. In 1987, Choy et al. [17] describe the use of laser in percutaneous disc surgery.

With the advancement in biomedical and imaging technologies over the years, new methods and modalities have emerged with variable techniques, advantages, and safety profiles.

There are six major types of PD:

1. Chemonucleolysis.
2. Automated percutaneous lumbar discectomy (APLD).
3. Percutaneous laser disc decompression (PLDD).
4. DeKompressor.
5. Nucleoplasty.
6. Percutaneous endoscopic lumbar discectomy (PELD).

8.3 Chemonucleolysis

This is the oldest of the PD techniques, as mentioned earlier, which was described by Smith in 1964 [14]. The two major enzymes used for this purpose are collagenase and chymopapain.

Collagenase is synthesized by *Clostridium histolyticum* consists of varied subenzymes that split the collagen fibers at different locations. The purified collagenase is relatively specific for type 2 collagen, seen mainly in the nucleus pulposus [18]. Collagenase did not gain a significant traction in the clinical treatment of LHD, and there are paucity of literature or evidence for its benefit.

Chymopapain is a proteolytic enzyme derived from the latex of the papaya plant. It catalyzes the hydrolysis of proteins in the nucleus pulposus, decreasing the affinity for water molecules by the proteoglycans, thus causing disc desiccation. The pressure in the disc is lowered, so the disc protrusion decreases, which relieves the tension on the nerve root. Chymopapain is immunoreactive and can be detected in the plasma 30 min after injection, and the half-life is 3 days [18].

Guha et al. [19] published a prospective observational study of 112 patients with magnetic resonance imaging (MRI) proven lumbar disc herniation who underwent

treatment with chymopapain chemonuleolysis and were followed up for 5 years. Majority of patients (83%) had excellent/good results, whereas 10% were unchanged and 7% were worse after the procedure. Also noted that the younger patients with single-level discs at L5–S1 had the most successful outcome (Fig. 8.1).

Gibson and Waddell in a Cochrane review [20] found five randomized clinical trials (RCT), which compared the efficacy of chemonucleolysis using chymopapain versus placebo, and the combined results clearly showed that chymopapain was more effective than placebo whether rated by the patients, surgeons, or independent observers. Five trials compared chymopapain to open discectomy of which two trials showed worse results as rated by patients at 1 year. The remaining three trials showed worse results as rated by surgeons at 1 year.

Couto et al. [21] conducted a meta-analysis of 22 clinical trials and concluded that chemonucleolysis with chymopapain was superior to placebo, although comparison to surgery was inconclusive, as the studies were too heterogeneous.

One of the main adverse effects of the treatment with chymopapain was allergic reactions including anaphylaxis with an occurrence of 1.5–2%. More serious and catastrophic adverse events were paraplegia, lumbar subarachnoid hemorrhage, and

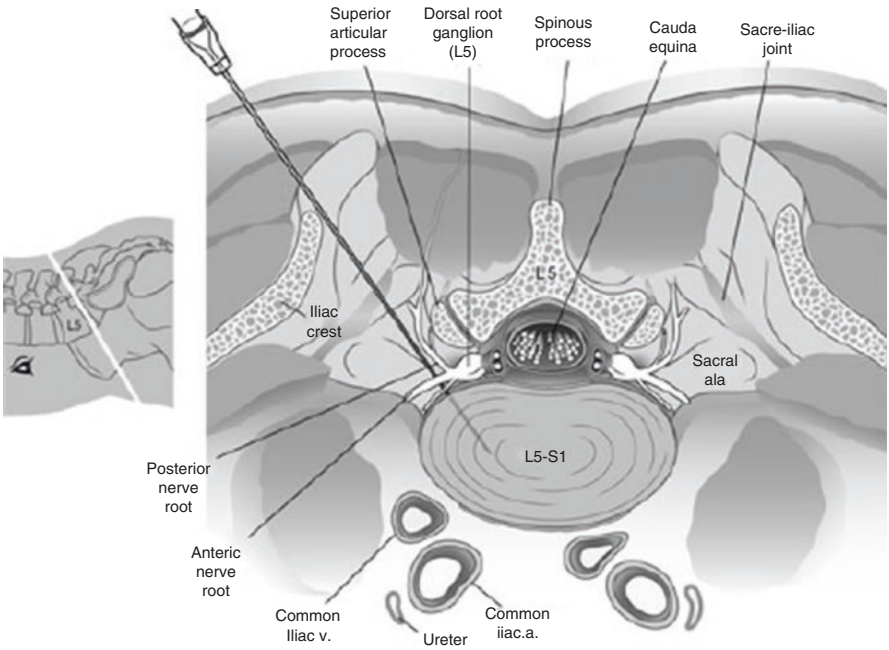

Fig. 8.1 Axial diagram of L5/S1 discography. The needle enters the posterolateral aspect of the intervertebral disk, just inferomedial to the exiting L5 nerve root. The inset indicates the approximate plane of the L5/S1 disk and needle. All intradiscal treatments share the common element of introducing a hollow needle or introducer cannula percutaneously into the nucleus pulposus of the intervertebral disk (Reproduced with permission from: Rathmell JP. *Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine.* Philadelphia: Lippincott Williams & Wilkins; 2006:107; Fig. 9-7)

death, due to peripheral or intrathecal injections [22]. Nordby et al. [23] evaluated the safety of chymopapain on the basis of 121 "serious" and "unexpected" adverse effects among 135,000 patients in the US reported to the Food and Drug Administration between 1982 and 1991. The incidents ranged from fatal anaphylaxis (seven cases) to infections, hemorrhage, and neurological deficits. The overall mortality rate was 0.019%. This, coupled with the fact that the company that produces chymopapain stopped its production, has made chymopapain administration extremely uncommon.

Ethanol has also been used in the past as a method of chemonucleolysis. Ethanol produces a molecular splitting of proteoglycans that leads to a degradation of these components and a loss of their water-retaining capacity resulting in dehydration and chemical decompression of the disc. Ethanol remained unpopular due to excessive diffusivity and the lack of radiopacity leading to blind injection. But a new preparation that includes ethyl cellulose to make the alcohol solution more viscous and tungsten to facilitate radiological monitoring of the injection (marketed under ethyl alcohol gel or DiscoGel®) is showing promising results. Marcia et al. [24] report on a study of 71 patients who underwent ethyl alcohol gel chemonucleolysis with meaningful improvement in pain and disability and no observed clinical complications. However, further prospective randomized control trials are warranted.

8.4 Automated Percutaneous Lumbar Discectomy (APLD)

The introduction of percutaneous chemonucleolysis in 1964 heralded the beginning of new minimally invasive techniques for the treatment of LDH, with the aim to avoid the inherent complications of the traditional laminectomy and discectomy like scar tissue formation, injury to the muscle, the nerve roots and the dural sac, and the development of structural weakness of the lumbar spine due to excessive bone removal.

The initial attempt with percutaneous chymopapin chemonucleolysis was associated with a higher rate of undesired complications and adverse events which made practitioners shy away from its use. As a result, Hijikata [15] pioneered a manual percutaneous lumbar discectomy in 1975 as a method to decompress the disc by mechanical rather than enzymatic action. This method was made popular by Kambin and Gillman [25] in which they used a percutaneous technique with local anesthetic to place an introductory trocar followed by a cannula to pass through to the annulus fibrosis. A cutting instrument is then passed 2 cm beyond the cannula to fragment the herniated disc which is then removed by a specialty designed "punch forceps."

This manual technique required the insertion of relatively large cannulas (> = 6 mm in diameter) in the disc space, which raised the concern about possible nerve injury upon introduction of the cannula. Onik, an interventional radiologist, recognized the similarity between the vitreous material of the eye and the nucleus of the disc and proposed the use of redesigned ophthalmic equipment, known as the "Nucleotome," a mechanical probe with blunted tip, a side shaving port, and a vacuum generator to remove the nucleus pulposus by a "suction and cutting" action

while continuous irrigation is applied. The probe was small in size (2 mm in diameter) which minimized the risk of nerve root injury, while its automated action allowed rapid removal of the disc materials. This technique was subsequently named automated percutaneous lumbar discectomy [16, 25].

In a systematic review conducted by Manchikanti et al. [26] to evaluate the effectiveness of APLD, there were no RCTs that met their inclusion criteria. Only 19 observational studies met those criteria, and based on the quality of evidence scale developed by the U.S. Preventive Service Task Force (USPSTF) [27], the indicated evidence for APLD is limited for short- and long-term relief. The authors concluded that APLD may provide appropriate relief in properly selected patients with contained lumbar disc herniation.

Another systematic review by Ong et al. [13] looked into four RCTs [28–31], but all the trials presented with problems in their design, so the results were inconclusive. One observational study [32] showed that APLD was not inferior to microendoscopic discectomy and both techniques show satisfactory long-term efficacy and safety. The author concluded that APLD is efficacious in selected patient group with a low incidence of complication, with evidence score of 2B based on the GRADE guidelines [33] (Table 8.1).

Overall APLD is a safe procedure, with discitis being the main possible complication. Teng et al. [34] in their report of APLD of a prospective multi-institutional study which included 1825 patients, reported a 0.06% incidence of discitis, which was the only complication.

8.5 Percutaneous Laser Disc Decompression (PLDD)

In 1987, choy et al. [17] described the use of Nd:YAG laser to perform percutaneous nucleolysis. 18 G needle was inserted into the affected disc under fluoroscopic guidance, with the tip in the nucleus pulposus, then a quartz optical fiber was advanced which through a laser was activated. The absorption of the applied laser energy leads to vaporization of the water content of the nucleus pulposus and a change in its protein structure, causing a decrease in intradiscal pressure. Because the disc is a semi-rigid structure, a small change in volume is associated with a large change in pressure.

There are several types of laser that could be used—Nd:YAG, KTP, CO2, Ho:YAG, and diode laser. The wavelength, pulse interval, and pulse duration can all be adjusted to change the absorption of energy. Low absorption of the energy leads to a low volume of nucleus pulposus removed, while high absorption of energy can cause adjacent tissue damage [13].

There is only one RCT that was recently published, Brouwer et al. [35] conducted a multicenter randomized prospective trial with a non-inferiority design and two-year follow-up to assess the clinical effectiveness of percutaneous laser disc decompression compared to conventional microdiscectomy surgery. Hundred and fifteen patients were enrolled randomly allocated to PLDD ($n = 55$) or conventional surgery ($n = 57$). The main outcome measures for this trial were the Roland-Morris

Table 8.1 Grading recommendations

Grade of recommendation/ description	Benefit vs. risk and burdens	Methodological quality of supporting evidence	Implications
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1B/strong recommendation, moderate quality evidence	Benefits clearly outweigh risk and burdens, or vice vena	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1C/strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation but may change when higher quality evidence becomes available
2A/weak recommendation. High-quality evidence	Benefits closely balanced with risks and burden	RCIs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients or societal values
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients or societal values
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits. Risks, and burden; benefits, risk, and burden may be closely balanced	Observational studies or ease series	Very weak recommendations; other alternatives may be equally reasonable

Disability Questionnaire for sciatica, visual analogue scores (VAS) for back and leg pain, and the patient's report of perceived recovery. Three patients were excluded after randomization and seven patients lost to follow-up. The primary outcome measures showed no significant difference or clinically relevant difference between the two groups at two-year follow-up. The reoperation rate was 21% in the surgery group, which is relatively high, and with an even higher 52% in the percutaneous laser disc decompression group. The authors concluded that despite a small sample size of the study, a strategy of percutaneous laser disc decompression, followed by

surgery if needed, resulted in non-inferior outcomes compared to a strategy of microdiscectomy. Although the rate of reoperation in the percutaneous laser disc decompression group was higher than expected, surgery could be avoided in 48% of those patients that were originally candidates for surgery.

Schenk et al. [37] conducted a systematic review in 2006. There were no randomized controlled trials identified at that time, but 16 clinical trials were included in this review, representing a total of 1579 patients. Success rates varied from 75% to 87% with broad 95% CIs that made interpretation of success rates difficult. The authors concluded that scientific proof of PLDD's efficacy still remains relatively poor, though the potential medical and economic benefits of PLDD are too high to justify discarding it as experimental or ineffective on the sole basis of insufficient scientific proof.

Sing et al. [36] performed a systematic review in 2013; while no RCT was identified at that time, and there were 15 observational studies of moderate-to-high quality. All studies showed positive outcome regarding pain relief at >12 months. However, overall level of evidence (based on USPSTF quality of evidence scale) for percutaneous lumbar laser disc decompression is limited for short- and long-term relief.

The most common complication of PLDD is discitis, both aseptic and septic, between 0% and 1.2% [36]. Aseptic discitis is likely secondary to thermal damage to either the disc itself or the vertebral endplates. In a case series in which CO2 laser was used, they reported an 8% incidence of thermal nerve root damage. As the CO2 laser needed a fixed metal cannula to be introduced to the disc, it is postulated that it is the heating of the metal cannula that caused such a high incidence of nerve root damage. As such, this complication should not be taken to represent all PLDD techniques [37].

8.6 DeKompressor

The Dekompressor® system (from Stryker) is a single-use probe intended for percutaneous discectomies under fluoroscopic imaging. The probe (a titanium auger) is introduced through a 1.5-mm-diameter cannula after the insertion of a hollow 17 G cannula into the disc, and the auger is connected to a disposable rotational motor, which mechanically aspirates nucleus material along the proximal chamber. The device removes a predetermined amount of disc material from the herniated disc, reducing pressure in the disc and the surrounding area. Advantages purported by proponents are that Dekompressor does not accelerate disc degeneration, allows collection of disc material for histology, and has minimal damage to adjacent tissues [38].

Manchikanti et al. [39] performed a systematic review in 2013, no RCT met their inclusion criteria and only three non-randomized prospective studies were evaluated [38, 40, 41]. Although these studies showed positive short- and long-term results with follow-up over 6 and 12 months. The level of evidence for percutaneous discectomy with Dekompressor® is limited.

Erginousakis et al. [42] presented RCT in 2011 comparing Dekompressor against conservative treatment (analgesics, anti-inflammatory drugs, muscle relaxants, and

physiotherapy) with a follow-up of 2 years. There was an 86% decrease in pain scores in the Dekompressor group versus 36% in the conservative group.

An observational study by Lemcke et al. [43] compared results of Dekompressor against nucleoplasty. Both groups had reductions in VAS scores and improvement in ability to work and to participate in activities of daily living, demonstrating that both Dekompressor and nucleoplasty are efficacious.

Recent long-term outcome study by McCormick et al. [44] investigated the long-term efficacy of percutaneous disc decompression with Dekompressor for discogenic radicular pain that has failed conservative management. Seventy patients underwent the procedure, and 40 and 25 patients were successfully contacted at 1- and 8-year follow-up, respectively. Using intention to treat analysis, at 1 and 8 years, numerical rating scale (NRS) pain scores were reduced >50% in both groups 47% and 29%, respectively; Oswestry Disability Index (ODI) score were improved >30% in 43% and 26% of patients, respectively. Of the patients who followed up at 8 years, 36% had undergone surgery.

Overall, this procedure has a low reported complication rate, and only one serious complication related to critical failure of the Dekompressor probe was reported. When the probe was removed after operating, the instrument tip broke off and remained embedded in the patient. The tip was needed to be removed surgically, and the patient recovered without any major complications [45].

8.7 Nucleoplasty

Nucleoplasty is an innovative percutaneous disc decompression procedure developed by ArthroCare. Nucleoplasty uses coblation technology, which is a controlled, non-heat driven process of tissue ablation.

Nucleoplasty involves removing a portion of the nucleus tissue using a 1 mm diameter bipolar instrument with radiofrequency energy that excites the electrolytes in the disc material creating a highly focused plasma field around the electrodes. The energized particles have a sufficient force to break down molecular bonds, which dissolves the soft-tissue material of the nucleus pulposus, producing a zone of thermal coagulation. Thus, nucleoplasty combines coagulation and tissue ablation (patented Coblation technology). Removal of tissue at relatively low temperatures (typically 40–70 °C) preserves the integrity of surrounding healthy tissue, therefore reducing the risk of damage to remaining disc tissue and the endplate cartilage [46, 47].

Nucleoplasty, sometimes also referred to as plasma disc decompression (PDD), is one of the most published technique among the PD procedures in recent years. There is one RCT published by Gerstzen et al. [48] in 2010, this was a multicenter randomized controlled clinical study and 90 patients who had sciatica associated with a single-level lumbar contained disc herniation were enrolled. These patients were refractory to initial conservative care and one epidural steroid injection. Participants were randomly assigned to receive either nucleoplasty (46 patients) or transforaminal epidural steroid injection (TFESI) (44 patients, up to two injections).

Patients in the plasma disc decompression group had significantly greater reduction in leg pain scores, ODI, and 36-Item Short Form Health Survey (SF-36). During the two-year follow-up, 56% of the patients in the PDD group and 28% of those in the TFESI group remained free from having a second procedure, following the study procedure. Adverse events, including injection site pain, increased leg or back pain, weakness, and lightheadedness, were observed in five patients in the PDD Group and seven in the TFESI Group.

A prospective comparative study by Adam et al. [49] compared patients with disc herniations <6 mm who underwent nucleoplasty (80 patients) to patients with herniations >6 mm that underwent open microdiscectomy (80 patients). Although the initial drop in VAS scores in the microdiscectomy group was more pronounced, the VAS scores between the two groups were similar by the end of 1 year. Compared to microdiscectomy, significantly more patients who underwent nucleoplasty returned to work.

Gerges et al. [50] published a systematic review on the effectiveness of nucleoplasty in 2010. The review included one RCT and 13 observational studies. The quality of evidence for improvement in pain or function after a nucleoplasty procedure is Level II-3, based on the quality of evidence developed by USPSTF for therapeutic interventions. The recommendation is level 1C based on the Grading Recommendation, strongly supporting the therapeutic efficacy of this procedure. However, the authors enforce the need for prospective randomized controlled trials with higher quality of evidence to confirm efficacy and risks and to determine ideal patient selection for this procedure.

In 2013, Manchikanti et al. [47] published and updated a systematic review including one RCT and 14 observational studies. The review concluded that there is limited to fair evidence for nucleoplasty in managing radicular pain secondary to contained disc herniations.

The majority of reviewed studies reported no significant complications related to nucleoplasty. However, Gerszten et al. [48] reported that 11% of patients in the nucleoplasty group had procedure-related adverse events such as increased radicular pain, pain at the injection site, increased back pain, increased weakness, and increased muscle spasms. One study by Azzazi et al. [51] had a 10% discitis rate, but it resolved in all five patients by 2 months. Rathmell et al. [52] described that even though the introducer cannula used for nucleoplasty is larger in diameter than the typical 22-G spinal needle used to perform discography, there is no evidence to suggest that there is a higher complication rate associated with the use of this large-bore introducer.

8.8 Percutaneous Endoscopic Lumbar Discectomy

Percutaneous endoscopic lumbar discectomy is a relatively new technique for the decompression of the lumbar disc space and removal of nucleus pulposus via a posterolateral approach. This was originally described by Mayer et al. [53] in 1987 but received more attention in the early 1990s.

In this technique, a working cannula is placed at the dorsal lateral border of the disc, then the disc space is visualized with an endoscope. The disc space is opened with anulus trephines and the nucleus pulposus is removed with forceps and an automated shaver system under intermittent endoscopic control [54]. PELD can be subclassified into the percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) according to the approach to the herniated disc material.

In 1993, Mayer et al. [54] published a study of 30 patients who underwent this procedure. The results were graded by the percentage of symptom relief and their own assessment of the results according to four categories (excellent/good/fair/bad). Patients were followed-up for 6 months, and 22 patients reported excellent or good relief, six patients reported fair relief, and two patients reported bad relief. Of these 30 patients, seven ultimately underwent open lumbar microdiscectomy, but the author indicated that three of them were operations on the same level or site of the procedure (true failures) and four were on a different level or site (false failures). There was only one complication in the study with one patient developing acute spondylodiscitis 36-h after the procedure. The patient was then immobilized and treated with antibiotics which led to the relief of the symptoms within 5 days.

In 2008, Ruetten et al. [55] published a prospective randomized controlled trial comparing the results of endoscopic interlaminar and transforaminal lumbar discectomies with the conventional microsurgical technique. In this study, 200 patients were enrolled but only 178 patients followed up for the full 24 months of the study. The results showed significant improvement in VAS pain scores, ODI scores, and North American Spine Society Instrument scores in both groups. After 2 years, 82% of the patients no longer had leg pain, 14% of patients reported pain occasionally or the pain was greatly reduced, and 4% of the patients experienced essentially no improvement. The differences in results between the groups were not significant. The recurrence rate was 6.2% with no difference between the groups. There were no serious complications in either group, such as dural/nerve injury or cauda equine syndrome. However, in the surgery group, two patients had postoperative bleeding, one patient suffered from delayed wound-healing, one patient developed a soft tissue infection, and three patients developed transient urinary retention. The complication rates were significantly elevated in the surgery group ($P < 0.05$). Another significant difference was in the mean postoperative work disability days which were 25 days in the PELD group versus 49 days in the surgery group ($P < 0.01$). Although the clinical results of the percutaneous endoscopic technique are equal to those of the microsurgical technique, the study pointed that there are advantages of the endoscopic technique in rehabilitation, complications, and reduced traumatization. With endoscopic surgery is a sufficient and safe supplementation and alternative to microsurgical procedures.

Most recent meta-analysis by Li et al. [56] compared PELD and standard discectomy (SD). The meta-analysis compiled 1301 cases from four randomized controlled trials and three retrospective studies. Compared with SD, PELD showed shorter operative times, less blood loss, shorter hospital stays, and shorter mean disability periods. However, there were no significant differences in the visual

analogue scale (VAS) scores at the final follow-up, Macnab criteria at the final follow-up, complications, recurrence rates, or reoperation rates. The authors concluded that PELD can be a feasible alternative to the conventional surgical approach in the treatment of the LDH, but high-quality RCTs with sufficiently large sample sizes are necessary to further confirm these results.

An important point was mentioned in this study that could apply not only to PELD but also to all of the minimally invasive PD technique, is the steep learning curve that could be the main reason contributing to complication and the heterogeneity of results. Referring to the studies by Wang [57] and Lee [58] which have shown that the complication rate remarkably decreased after the first-twenty patients. To overcome the problem of the steep learning curve, Gibson [59] recommend that surgeons should start performing the procedure under experienced guidance, after attending cadaveric workshops. Additionally, the surgeon should have enough patience to learn PELD, especially for those who are unfamiliar with percutaneous techniques.

8.9 Conclusion

With the growing popularity of minimally invasive techniques in almost all fields of surgery, spine interventions have received significant attention and development over the last two decades. Percutaneous discectomy presents as a safe and less invasive technique than microdiscectomy, which has been considered the "gold standard" for the treatment of herniated discs.

Nucleoplasty is an attractive treatment option because of its minimally invasive nature and the corresponding decreased risk of structural damage to the muscles, bone, ligaments, and nerves. This may result in a lower prevalence rate of failed back surgery syndrome. In addition, the patients are expected to have less back pain, shorter hospitalization stays, and shorter recovery periods than conventional surgery. Furthermore, the procedure can be done under local anesthesia which adds a significant economic advantage, especially in the current environment with increased emphasis on cost and efficiency.

In general, there is a paucity of high-quality literature around percutaneous discectomy which is multifactorial: small sample sizes, short durations of follow up, and large losses of patients' data on subsequent follow ups. It is difficult to compare the results of different studies due to wide variations in inclusion criteria, interventional protocols, and outcome measures. And it is extremely hard to conduct double-blinded, placebo-controlled studies with interventional procedures, and there are additional ethical concerns about exposing patients to the risk of the procedure without any added benefit in the placebo arms.

With any intradiscal technique, discitis is an inherent risk that can be difficult to diagnose and treat. Rathmell et al. [52] recommend the regular use of prophylactic antibiotics, a comprehensive knowledge of the anatomy of the intervertebral space and the meticulous use of radiographic guidance in multiple planes. Additionally, an adequate level of sedation that still allows the patient to communicate verbally is

warranted to notify the proceduralist of potential nerve damage before permanent injury.

While open surgical discectomy is the best option for sequestered, non-contained or large herniations, PDD has been demonstrated to be the best option to treat small contained disc herniations [60–62].

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